Development of an Integrated Adaptive Transit Signal Priority (ATSP) and Dynamic Passenger Information (DPI) System

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1. Why this Research was undertaken

Computer-aided dispatch (CAD), Transit Signal Priority (TSP) and Dynamic Passenger Information (DPI) have been identified as promising ITS technologies to improve the quality, reliability and efficiency of traditional transit service, the perception of transit, and create the opportunity for passengers making informed travel choice. In fact, TSP and DPI have been becoming important elements of Bus Rapid Transit (BRT) systems. These three ITS technologies share common critical software and hardware elements. They all require onboard vehicle location technology and information processing, and the information exchanging capabilities between fleet vehicles and dispatch or traffic control infrastructure. Despite the fact that the Automatic Vehicle Location/Advanced Communication System (AVL/ACS) for today's CAD system already has the critical elements in place to support both TSP and DPI features, TSP and DPI are separately implemented. As a result, multiple GPS units, computer hardware and communication links need to be installed on a single bus. The disintegration not only causes redundant capital investments and costs for operation and maintenance, but also prevents transit from getting full benefits enabled by the ITS technologies.

In collaboration with San Mateo County Transit District (SamTrans), California PATH and Caltrans have developed and field tested an Adaptive TSP system on a 6.6 miles long road segment along El Camino Real. This task is a continuous research effort to expand the ATSP system to include the DPI features and to utilize the existing ACS system to accommodate the communication needs for the generation of priority requests and dynamic passenger information.

2. What was done

An open system architecture has been developed to build the integrated ATSP/DPI upon the existing AVL/ACS, with layered database structures and processing modules, and various interfaces for data collection and information dissemination. An integrated, flexible and scalable database has also been developed to support the open architecture ITS applications. Bus arrival time prediction model has been expanded to include transit operation factors in the prediction algorithm such that it can serve both short-term prediction for ATSP and long-term prediction for DPI. Web APIs have been developed to deliver passenger dynamic information in various ways, including pre-trip planning, information querying by smart phones and information display at bus-stops.

Dynamic polling strategies that utilizing the available channel capacity of the existing ACS for needed-based bus location polls for ATSP have been developed, implemented and field tested in both the laboratory environment and in the real-world operation environment. In order to overcome the lack of access to ACS processing software, an ACS emulation approach was adopted for testing the capability of existing ACS in supporting the integrated ATSP/DPI and the resulted performance of ATSP and DPI.

Field operational test were conducted on SamTrans revenue bus routes 390 and 391 that travel along El Camino Real (State Route 82). The implemented ATSP arterial is the central portion of bus routes 390 and 391, which is 10 miles long and covers 50 signalized intersections between 42nd Avenue in San Mateo and Bayhill Road in San Bruno. Fifteen SamTrans buses that provide revenue service on routes 390 and 391 were instrumented with cell-phone-based AVL systems to provide inputs, in addition to ACS data feeds, to the ACS emulation platform.

3. <u>Results of the Research</u>

A four-week-"before" and an eight-week-"after" field operational tests along the 50-signal arterial achieved very positive results and demonstrated the effectiveness of integrated ATSP/DPI.

Dynamic polling under ACS emulation provided necessary additional bus location updates for the needs of ATSP without overwhelming the channel capacity of the existing ACS. On average about 120 polls were dynamically inserted along the 10-mile-long ATSP corridor for the average travel period of 55 minutes. The average time gap between inserted polls was 27 seconds. Ninety-seven percent (97%) of inserted polls were processed without the collision of multiple competing polling requests. Even when a request collision did happen, the delay in responding to inserted polling request was within 4 seconds.

ATSP under emulated dynamic polling worked as expected. The positive impacts of ATSP on transit operation are shown in several aspects. In comparison with the scenario of ATSP off, when ATSP was on,

- Bus trip travel time was reduced by 4.4% for southbound trips and by 1.4% for northbound trips;
- Bus total intersection delay was reduced by 19.4% for southbound trips and by 9.2% for northbound trips;
- Number of stops at prioritized intersections was reduced by 5.9% southbound and by 4.1% northbound;
- Bus running speed was increased by 4.3% southbound and by 1.5% northbound.

All these changes are statistically significant at the 5% level. Moreover, the percentage of buses running over 5 minutes behind the schedule was reduced by 27%.

Dynamic passenger information based on the integrated ATSP/DPI has been displayed to the public at Millbrae Station kiosks. Prediction error of bus arrive time was within +/- 2 minutes when the bus was 40 minutes away. SamTrans personnel has been site observing multiple times and found the information "is remarkably accurate". Integrating DPI with ATSP improved the performance of DPI, as the inserted polls for ATSP purpose contributed for better prediction results. The absolute error mean was reduced by 16% in the section covering four time-points within the ATSP corridor.

To address the deployment issues, we concluded that:

- The ATSP/DPI system architecture is suitable for the large scale implementation;
- The existing ACS can be used as the communication backbone to facilitate TSP requests and to support both ATSP and DPI features; and
- The integrated ATSP/DPI contributes to the improved DPI with additional bus location updates becoming available.

4. <u>Researcher recommendations</u>

It was recommended that AVL/ACS vendors implement smart channel management technologies such as dynamic polling to expand the AVL/ACS to serve transit fleet management, TSP and DPI with one integrated system. It was also recommended that transit agencies adopt the integration approach when deploying TSP and DPI not only to reduce the investment but also to achieve better performance enabled by the integration.

The ATSP system is built upon GPS based bus AVL systems. GPS signals may be blocked by tall buildings, trees or overpasses, which would degrade the TSP performance at certain geographic locations. Dedicated Short Range Communications System (DSRC) is a low-cost wide bandwidth communications infrastructure that is currently developed under the Vehicle-to-Infrastructure Integration (VII) program and is expected to be massively deployed for automobile applications in the near term. It is recommended that the possibility of applying DSRC is to be explored to as a communications base to enhance ATSP/DPI performance.

5. Implementation strategies

- Assist AVL/ACS venders and transit agencies to assess the possibility of deployment of dynamic polling strategies: Many transit agencies possess advance communication system (ACS) whose communication protocols can be modified to enable inserted polling to meet ATSP needs. ACS only requires minimum software and protocol changes to the ACS bus computers and central ACS computer therefore little costs will be involved. We will provide requirement specifications for incorporating bus borne arrival prediction and inserted polling protocol for transit agencies requesting modification of the existing ACS systems or the inclusion in the system requirements for new ACS procurement. We can also provide technical support on software modifications to the ACS bus to enable prediction, and protocol changes to the ACS bus and central system to allow inserted polling.
- Assess candidate corridors for ATSP/DPI deployment: ATSP requires that the corridors are instrumented with communications links between traffic signal systems and the traffic management center. We will provide requirements and assist traffic agencies to make modifications of the traffic controller software enabling traffic and signal status data be sent to ATSP requester in real-time and to adjust signal phase according to ATSP requests.
- Assist transit agencies for integrated database management and at-station DPI display: Efficient database management is important for the integrated ATSP/DPI system with various data sources, data pre-processing and data aggregation, and information dissemination through various ways. We will provide transit agencies the database specifications and technical support on modification of database tools.

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